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Dotan et al.

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(54) VIRTUALIZATION PLATFORM FOR SECURED COMMUNICATIONS BETWEEN A USER DEVICE AND AN APPLICATION SERVER

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G06F 9/455 (2006.01)
G06F 15/16 (2006.01)

(52) **U.S. Cl.**
USPC **718/1**; 709/203

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,529,953	B1 *	3/2003	Van Renesse	709/223
6,791,980	B1 *	9/2004	Li	370/390
8,321,648	B2 *	11/2012	Condict	711/170
2005/0149481	A1 *	7/2005	Hesselink et al.	707/1
2007/0186212	A1 *	8/2007	Mazzaferri et al.	718/1

OTHER PUBLICATIONS

U.S. Appl. No. 12/854,641, filed Aug. 11, 2010 and entitled, Disposable Browser for Commercial Banking, pp. 1-19.
G. Decandia et al., "Dynamo: Amazon's Highly Available Key-value Store," SOSP 2007, pp. 205-218.
L. Lamport et al., "The Byzantine Generals Problem," ACM Transactions on Programming Languages and Systems, vol. 4, No. 3, 1982, pp. 382-401.
Hash tree, http://en.wikipedia.org/wiki/Hash_tree, Mar. 31, 2011, pp. 1-3.

* cited by examiner

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(57) **ABSTRACT**

A modular virtualization platform is provided for secured communications between a user device and an application server. A client-side computing device performs secured communications during a virtual session with an application server across a network. The client-side computing device loads a virtual machine client; and selects a remote module to serve as a virtualization server for the virtual session based on one or more performance factors. The virtual session is established with the selected module, and secured communications can occur between the client-side computing device and the application server via the virtual session of the selected module. The performance factors can be collected from a plurality of modules using a peer-to-peer gossip-based state notification process. A route list preferably stores the performance factors for a plurality of modules. The route list can contain pointers to a plurality of remote modules in a plurality of virtualization platforms, to increase reliability.

24 Claims, 9 Drawing Sheets

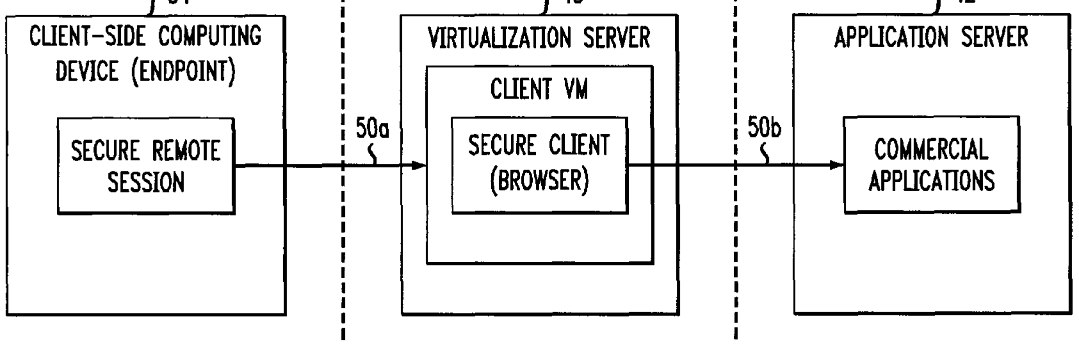


FIG. 1

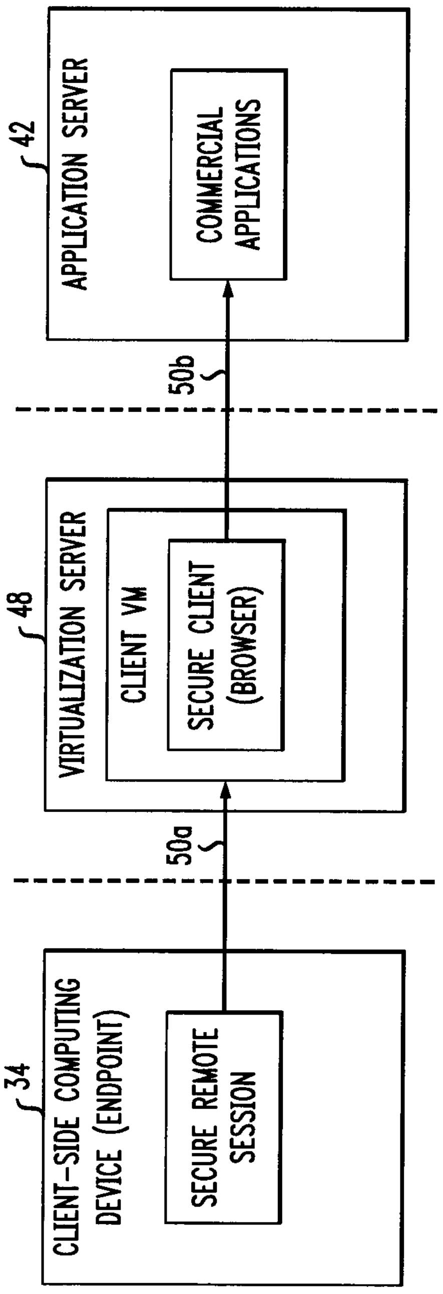

34
CLIENT-SIDE COMPUTING DEVICE (ENDPOINT)
SECURE REMOTE SESSION
50a
48
VIRTUALIZATION SERVER
CLIENT VM
SECURE CLIENT (BROWSER)
50b
42
APPLICATION SERVER
COMMERCIAL APPLICATIONS

FIG. 2

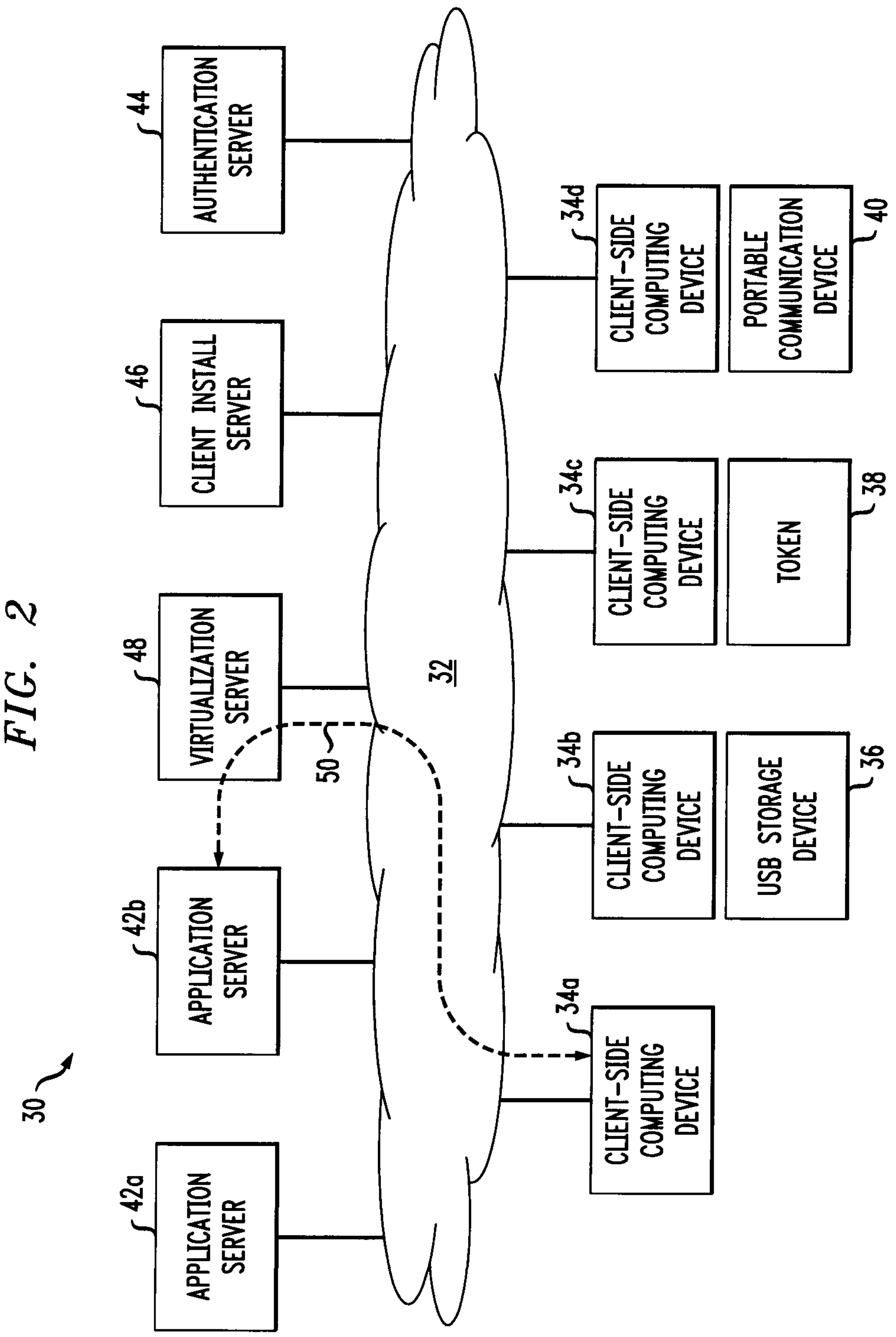

30
42a APPLICATION SERVER
42b APPLICATION SERVER
48 VIRTUALIZATION SERVER
46 CLIENT INSTALL SERVER
44 AUTHENTICATION SERVER
50
32
34a CLIENT-SIDE COMPUTING DEVICE
34b CLIENT-SIDE COMPUTING DEVICE
34c CLIENT-SIDE COMPUTING DEVICE
34d CLIENT-SIDE COMPUTING DEVICE
36 USB STORAGE DEVICE
38 TOKEN
40 PORTABLE COMMUNICATION DEVICE

FIG. 3

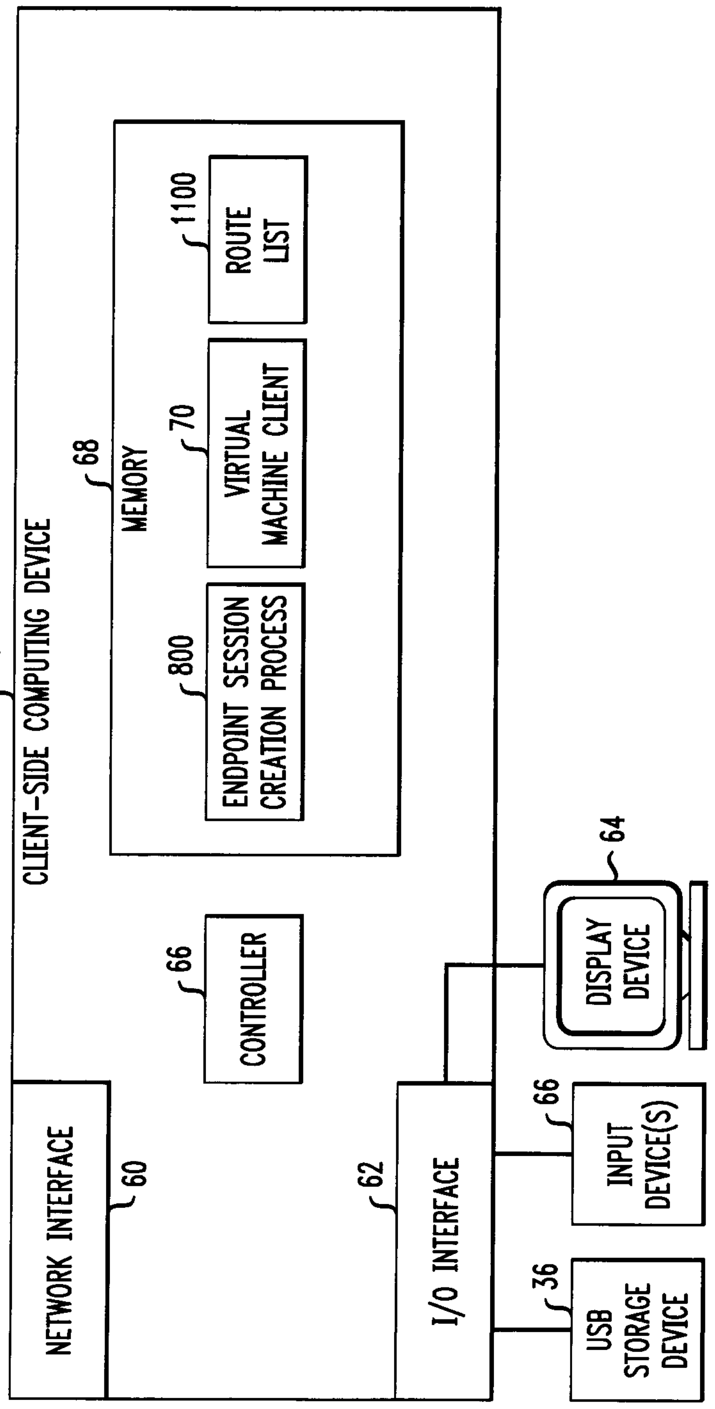

34
CLIENT-SIDE COMPUTING DEVICE
68
MEMORY
800
ENDPOINT SESSION CREATION PROCESS
70
VIRTUAL MACHINE CLIENT
1100
ROUTE LIST
66
CONTROLLER
60
NETWORK INTERFACE
62
I/O INTERFACE
64
DISPLAY DEVICE
66
INPUT DEVICE(S)
36
USB STORAGE DEVICE

FIG. 4

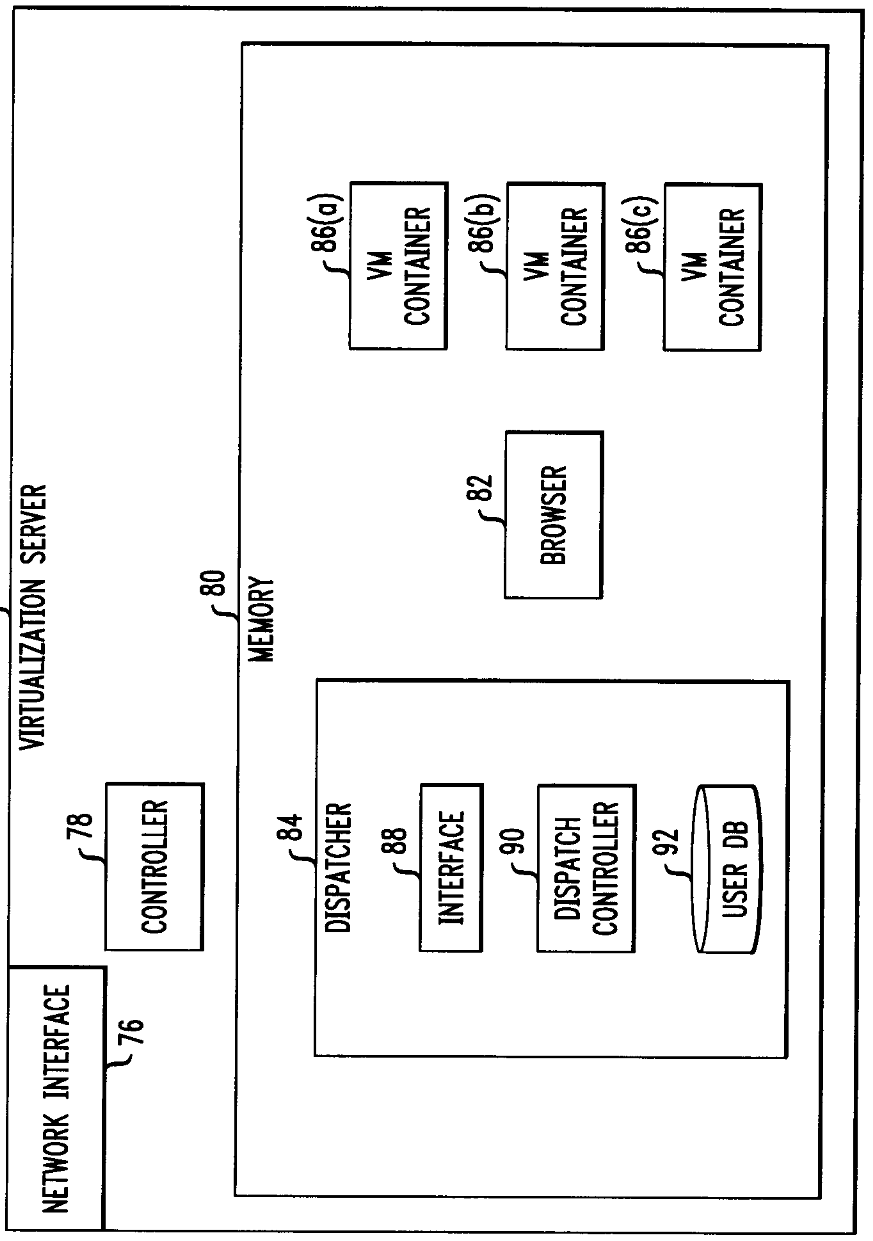

48 VIRTUALIZATION SERVER
76 NETWORK INTERFACE
78 CONTROLLER
80 MEMORY
84 DISPATCHER
88 INTERFACE
90 DISPATCH CONTROLLER
92 USER DB
82 BROWSER
86(a) VM CONTAINER
86(b) VM CONTAINER
86(c) VM CONTAINER

FIG. 5

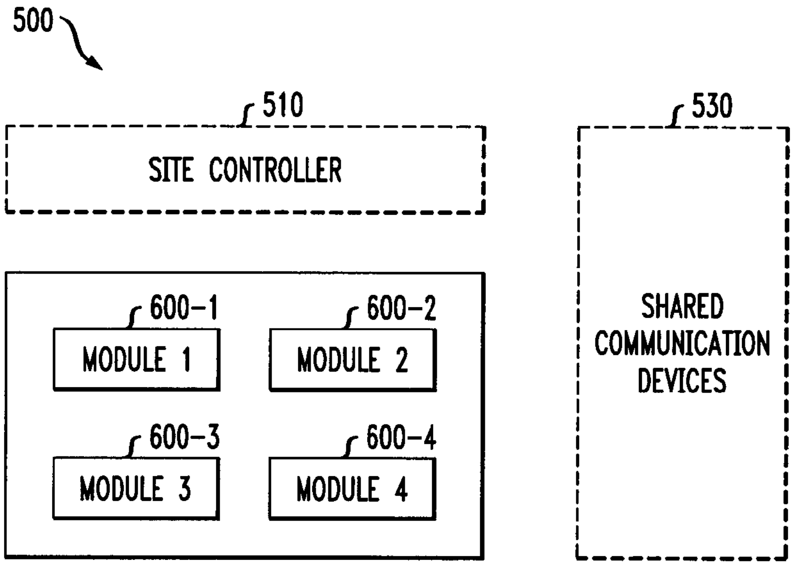

500
510
SITE CONTROLLER
600-1
MODULE 1
600-2
MODULE 2
600-3
MODULE 3
600-4
MODULE 4
530
SHARED COMMUNICATION DEVICES

FIG. 6

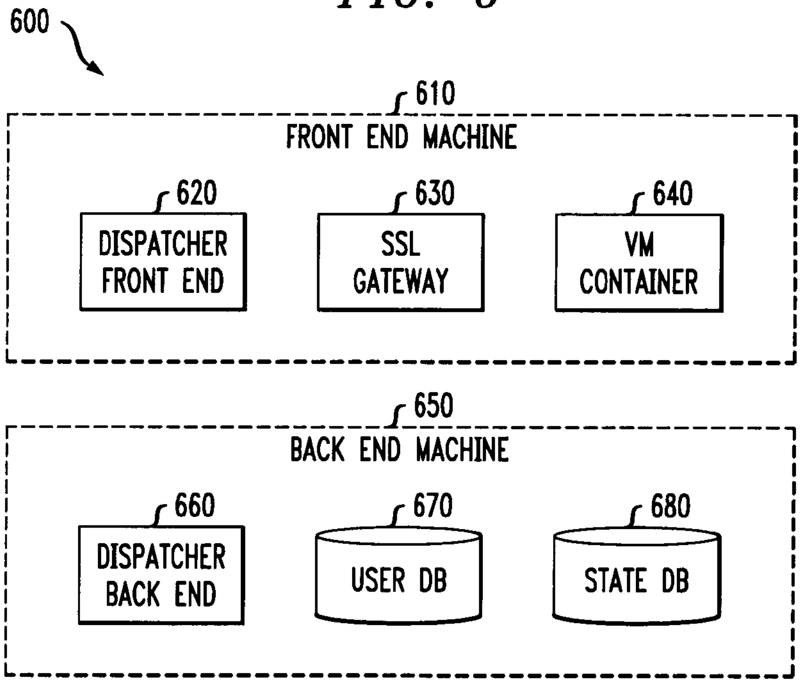

600
610
FRONT END MACHINE
620
DISPATCHER FRONT END
630
SSL GATEWAY
640
VM CONTAINER
650
BACK END MACHINE
660
DISPATCHER BACK END
670
USER DB
680
STATE DB

FIG. 7

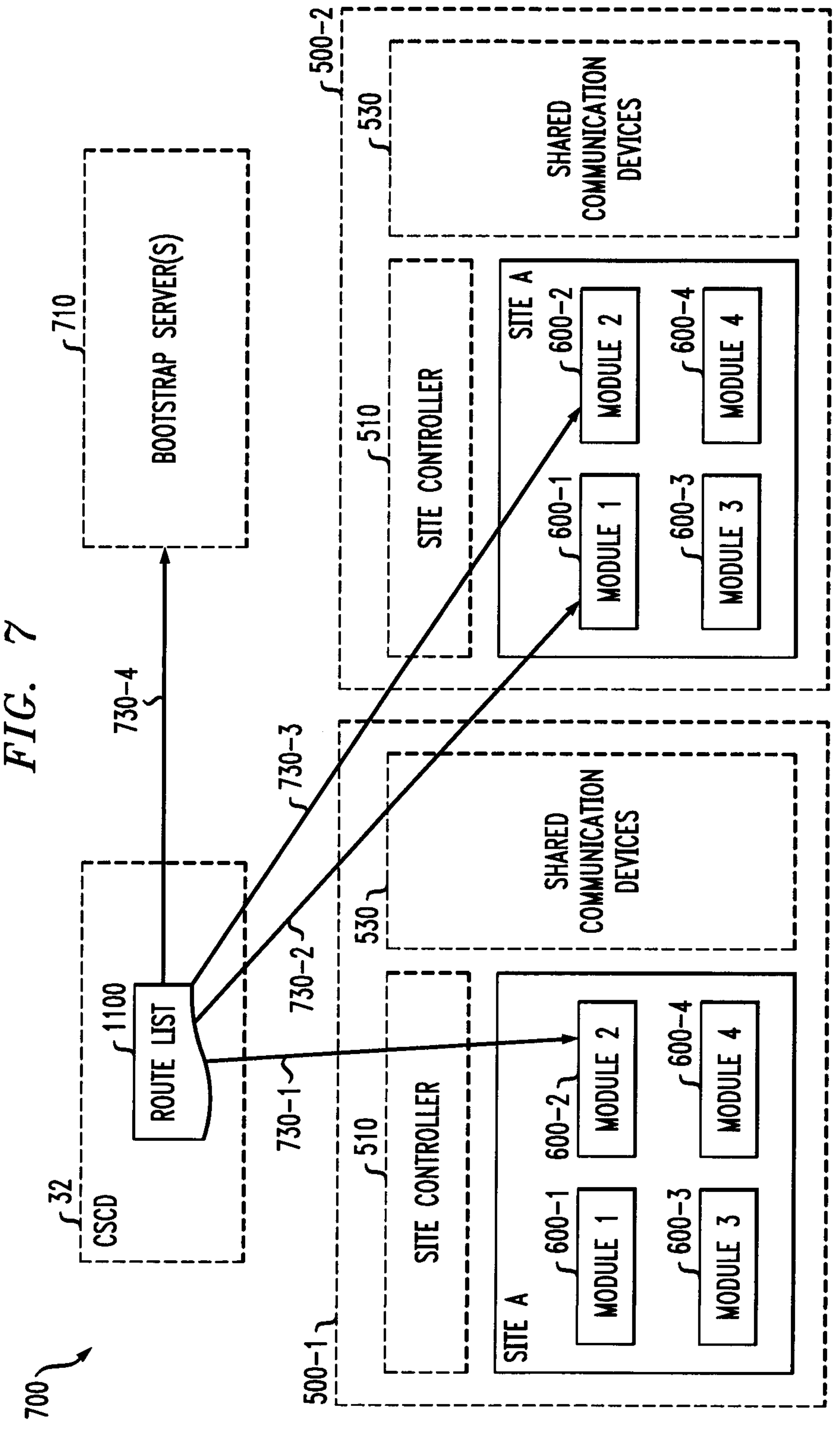
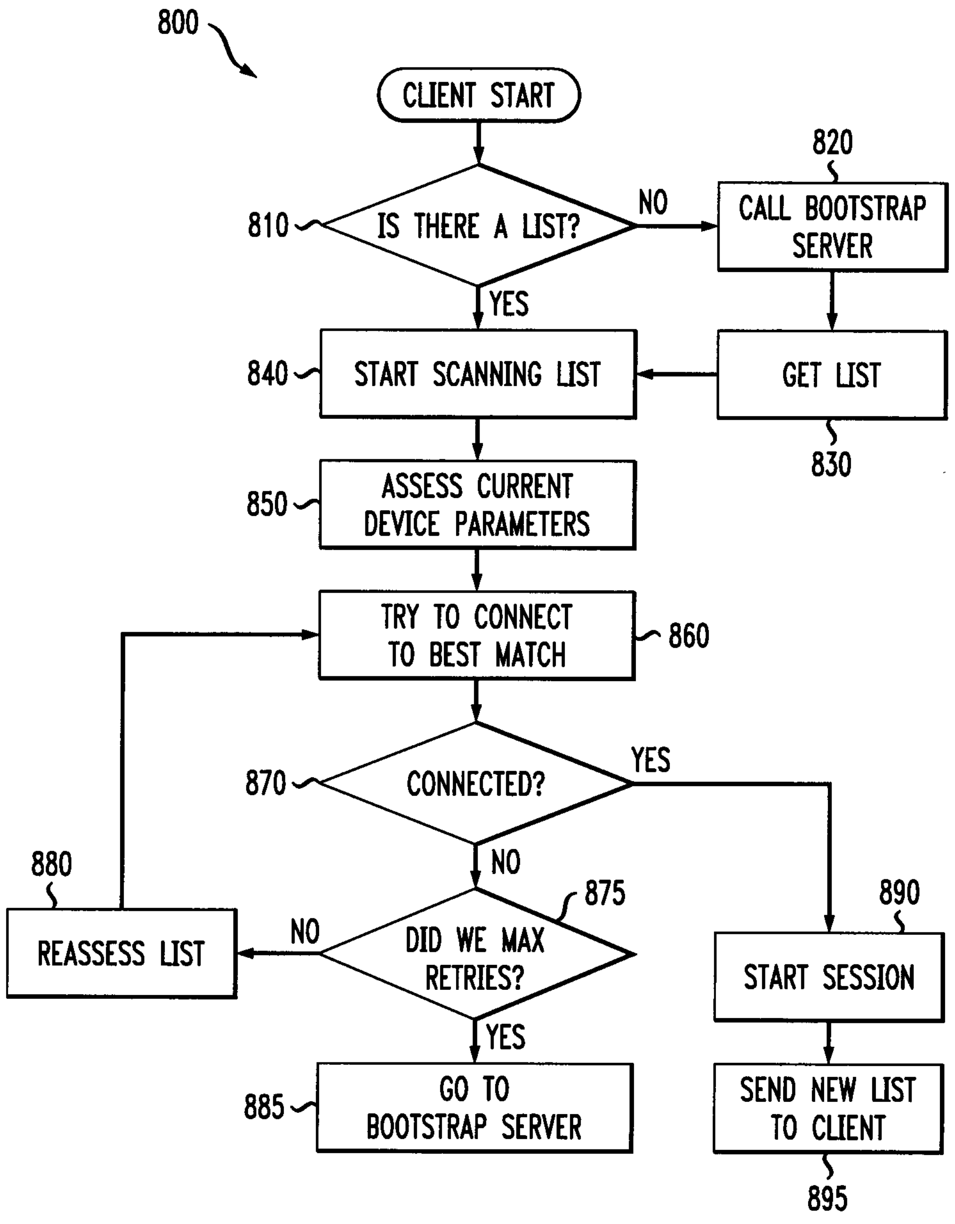

700
32
CSCD
1100
ROUTE LIST
730-1
730-2
730-3
730-4
710
BOOTSTRAP SERVER(S)
500-1
500-2
510
SITE CONTROLLER
530
SHARED COMMUNICATION DEVICES
SITE A
600-1
MODULE 1
600-2
MODULE 2
600-3
MODULE 3
600-4
MODULE 4

FIG. 8


800
CLIENT START
810
IS THERE A LIST?
NO
820
CALL BOOTSTRAP SERVER
YES
840
START SCANNING LIST
GET LIST
830
850
ASSESS CURRENT DEVICE PARAMETERS
TRY TO CONNECT TO BEST MATCH
860
870
CONNECTED?
YES
NO
875
DID WE MAX RETRIES?
NO
880
REASSESS LIST
YES
885
GO TO BOOTSTRAP SERVER
890
START SESSION
SEND NEW LIST TO CLIENT
895

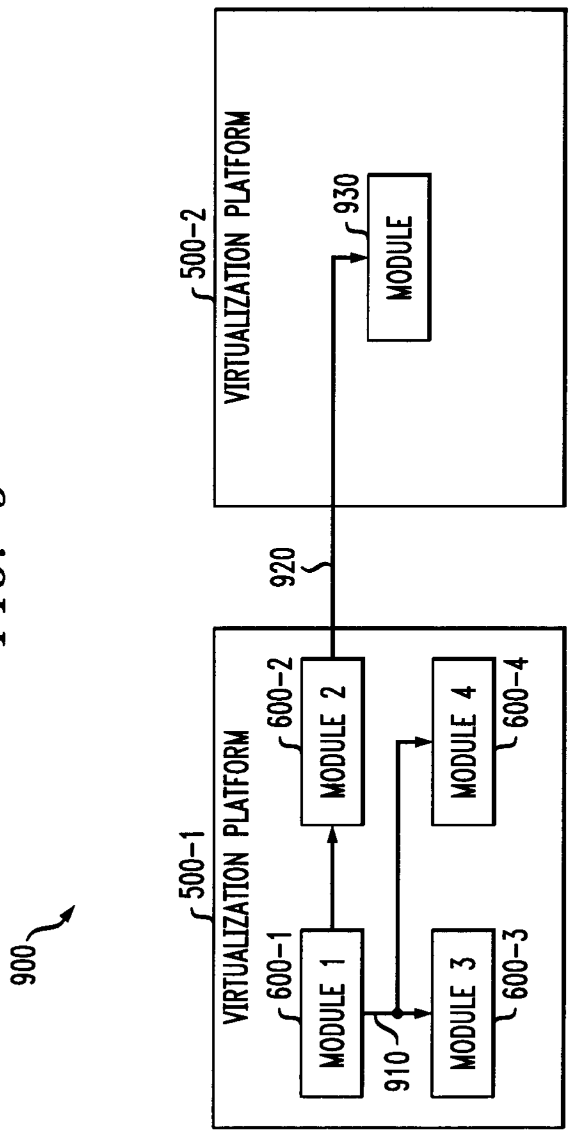

900
500-1
VIRTUALIZATION PLATFORM
600-1
MODULE 1
600-2
MODULE 2
910
MODULE 3
600-3
MODULE 4
600-4
920
500-2
VIRTUALIZATION PLATFORM
930
MODULE

FIG. 9

FIG. 10

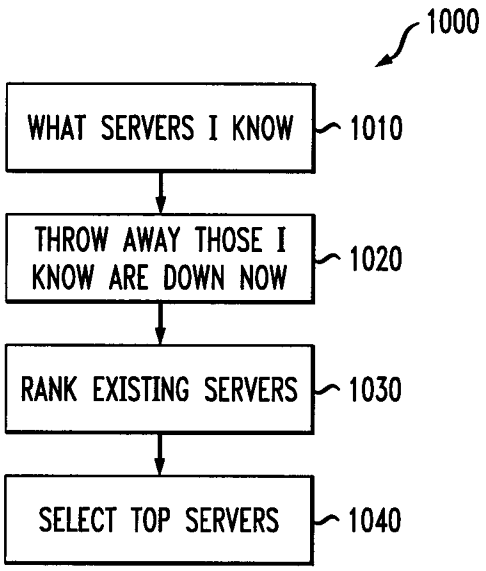
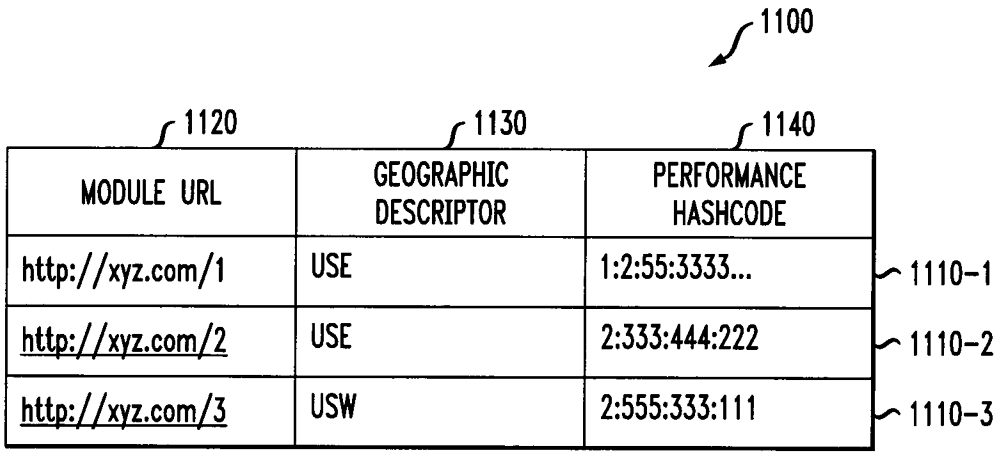


FIG. 11


1100
1120
1130
1140
1110-1
1110-2
1110-3

MODULE URL	GEOGRAPHIC DESCRIPTOR	PERFORMANCE HASHCODE
http://xyz.com/1	USE	1:2:55:3333...
http://xyz.com/2	USE	2:333:444:222
http://xyz.com/3	USW	2:555:333:111

VIRTUALIZATION PLATFORM FOR SECURED COMMUNICATIONS BETWEEN A USER DEVICE AND AN APPLICATION SERVER

FIELD OF THE INVENTION

The present invention relates generally to techniques for securing communications over a network and other types of communication systems.

BACKGROUND OF THE INVENTION

Malicious software (malware) is designed to harm or access a computer system without the informed consent of the owner. Malware is a serious threat to many computer systems, particularly in an online environment. Malware includes computer viruses, Trojan horses, worms and other malicious and unwanted software programs. Trojan horses, for example, install themselves on user machines without being perceived by the user. Trojan horses may then enable a controller to record data from an infected machine (e.g., key loggers), listen in on conversations (e.g., Man in The Middle or MiTM), or even hijack an HTTP session from within a browser (e.g., Man in The Browser or MiTB). Trojan horses are able to record keyboard entries at given web sites, and thereby steal the users' user names and passwords. Trojan horses are also able to change transactions as they occur. Thus, the user may think he or she is performing a legitimate transaction (e.g., paying a bill) but in reality the user is sending money to another account. Trojan horses also allow session hijacking, whereby a remote fraudster performs transactions via the user's infected machine.

A number of security techniques have been proposed or suggested for reducing the susceptibility of a user to such malware. For example, strong authentication methods, such as multi-factor authentication (such as "something you have" and "something you know") or a challenge response protocol can be used to improve the security of communications between the user and an application server over a network.

In addition, U.S. patent application Ser. No. 12/854,641, filed Aug. 11, 2010 and entitled "Disposable Browser for Commercial Banking," incorporated by reference herein and hereinafter referred to as the "'641 U.S. patent application," discloses a virtual environment for secure communications between a client-side computing device and a remote application server through a virtual computing environment provided by an intermediate virtualization server. The virtual computing environment includes a disposable component, allowing all settings to be initialized to a secure state after each user session.

In an e-commerce environment, reliability and resilience are also important requirements. Reliability is often measured as a percentage of time that a system is available. Resilience is the ability to provide and maintain an acceptable level of service even in the presence of faults and other challenges to normal operation. In addition, it is important that such systems maintain reliability and resilience, even as they grow. Scalability is the ability of a system to accommodate growth.

A need exists for improved techniques for reducing the susceptibility of a user to malware while maintaining acceptable measures of reliability, resilience and scalability.

SUMMARY OF THE INVENTION

The present invention in the illustrative embodiments described herein provides a modular virtualization platform for secured communications between a user device and an application server. In accordance with an aspect of the invention, a client-side computing device performs secured communications during a virtual session with an application server across a network. The client-side computing device loads a virtual machine client; and selects a remote module to serve as a virtualization server for the virtual session based on one or more performance factors. The virtual session is established with the selected module, and secured communications can occur between the client-side computing device and the application server via the virtual session of the selected module.

In accordance with another aspect of the invention, the performance factors are collected from a plurality of modules using a peer-to-peer gossip-based state notification process. A route list preferably stores the performance factors for a plurality of modules. The route list can be generated from a bootstrap point. The route list can contain pointers to a plurality of remote modules in a plurality of virtualization platforms, to increase reliability. The route list is optionally based on a hash tree format that indicates a distance to a given module.

The authentication techniques of the illustrative embodiments overcome one or more of the problems associated with the conventional techniques described previously, and permit users to work from a secure virtual environment, taking the form of a disposable browser environment, without direct interaction between malware and the remote application server, such as an online banking site. These and other features and advantages of the present invention will become more readily apparent from the accompanying drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary client-side computing device (CSCD) establishing a virtual session running on a virtualization server to allow for secured communications in accordance with the present invention;

FIG. **2** illustrates a network environment in which various embodiments of the present invention can be implemented;

FIG. **3** depicts an exemplary implementation of a CSCD of FIG. **2** in further detail;

FIG. **4** depicts an exemplary implementation of a virtualization server of FIG. **2** in further detail;

FIG. **5** is a schematic block diagram of an exemplary virtualization platform incorporating features of the present invention;

FIG. **6** is a schematic block diagram illustrating an exemplary module of FIG. **5** in further detail;

FIG. **7** illustrates the selection of a particular module by a CSCD using a route list, in accordance with an aspect of the present invention;

FIG. **8** is a flow chart describing an exemplary implementation of an endpoint session creation process that incorporates features of the present invention;

FIG. **9** illustrates the communication of gossip data among a number of modules;

FIG. **10** is a flow chart describing an exemplary process that may be performed by a given module to process collected gossip data; and

FIG. **11** is a sample table from an exemplary route list incorporating features of the present invention.

DETAILED DESCRIPTION

The present invention provides a virtualization platform for secured communications between a user device (referred to herein as a client-side computing device) and a remote application server. The invention will be described herein with reference to an exemplary communication system in which a client-side computing device communicates with an application server by means of a virtualization server. FIG. **1** illustrates an exemplary client-side computing device (CSCD) **34** establishing a virtual session running on a virtualization server **48** to allow for secured communications **50***a*, **50***b* (collectively, referred to as secured communications **50**) between the CSCD **34** and an application server **42** via the virtualization server **48**.

According to one aspect of the present invention, the virtualization server **48** may be implemented using a virtualization platform **500**, discussed further below in conjunction with FIG. **5**, that provides secured communications **50** between the CSCD **34** and an application server **42**. Among other benefits, the disclosed virtualization platform **500** demonstrates improved reliability, resilience and scalability. According to one aspect of the invention, discussed further below in conjunction with FIGS. **5** and **6**, the virtualization platform **500** employs a plurality of modules **600** that can be repaired or replaced in the event of a failure. In addition, additional modules **600** can be added to a given virtualization platform **500**, as well as adding entire virtualization platforms **500**, to accommodate growth. The virtualization server **48** of FIGS. **1** and **2**, for a given virtual session, can be executed on a given module in the virtualization platform **500**.

According to another aspect of the invention, discussed further below in conjunction with FIGS. **9-11**, each module is aware of the state of other modules in a given virtualization platform **500** and in other virtualization platforms **500** through a decentralized gossip-based state notification process. Generally, the various modules in a given virtualization platform **500** and in other virtualization platforms **500** communicate in a peer-to-peer manner similar to a mesh network. For example, a given module can report problems and/or one or more performance indicators to one or more other modules, which in turn, can repeat the information to other modules in the system.

According to yet another aspect of the invention, discussed further below in conjunction with FIGS. **7** and **8**, each CSCD **34** includes a route list **1100** and an endpoint session creation process **800** for selecting an appropriate module **600** to serve as the virtualization server **48** of FIGS. **1** and **2**, for a given virtual session, and to establish a session with the selected module **600**.

The CSCD **34** may represent a portable device, such as a mobile telephone, personal digital assistant (PDA), wireless email device, game console, etc. The CSCD **34** may alternatively represent a desktop or laptop personal computer (PC), a microcomputer, a workstation, a mainframe computer, a wired telephone, a television set top box, or any other information processing device which can benefit from the use of single sign-on techniques in accordance with the invention.

The CSCD **34** may also be referred to herein as simply a "user." The term "user" should be understood to encompass, by way of example and without limitation, a user device, a person utilizing or otherwise associated with the device, or a combination of both. An operation described herein as being performed by a user may therefore, for example, be performed by a user device, a person utilizing or otherwise associated with the device, or by a combination of both the person and the device. Similarly, a password or other authentication information described as being associated with a user may, for example, be associated with a CSCD device **34**, a person utilizing or otherwise associated with the device, or a combination of both the person and the device.

The application server **42** may be, for example, a remote application server such as a web site or other software program that is accessed by the CSCD **34** over a network **30**. The network **30**, may comprise, for example, a global computer network such as the Internet, a wide area network (WAN), a local area network (LAN), a satellite network, a telephone or cable network, or various portions or combinations of these and other types of networks.

As previously indicated, the virtualization server **48** may be implemented using a virtualization platform **500**, discussed further below in conjunction with FIG. **5**, that provides secured communications **50** between the CSCD **34** and an application server **42** with improved reliability, resilience and scalability.

FIG. **2** illustrates a network environment **30** in which various embodiments of the present invention can be implemented. Network environment **30** includes a network **32** (such as, for example, the Internet). Network environment **30** also includes a set of client-side computing devices (CSCDs) **34**, depicted as CSCDs **34**(*a*)-**34**(*d*), that are connected to the network **32**. Some CSCDs **34**, such as CSCD **34**(*b*), attach to a small external portable storage device such as a Universal Serial Bus (USB) "thumb drive" or storage device **36**. A user of a CSCD **34**, such as CSCD **34**(*c*), may hold a token device **38**. A user of a CSCD **34**, such as CSCD **34**(*d*), may hold a portable communication device **40**, such as a cellular phone.

Network **32** also connects to one or more application servers **42**, depicted as application servers **42**(*a*)-**42**(*b*), an authentication server **44**, a client install server **46**, and a virtualization server **48**. It should be understood that although one each is shown of the authentication server **44**, client install server **46**, and virtualization server **48**, in some embodiments there may be multiple instances of each, while in other embodiments, some of these elements may be omitted. Furthermore, some of these elements may be replaced with various combinations of other devices that perform similar tasks.

As discussed above in conjunction with FIG. **1**, in one exemplary mode of operation, the CSCD **34**(*a*) may establish a virtual session running on virtualization server **48** to allow for secured communications **50** between CSCD **34**(*a*) and an application server **42**(*b*) via the virtualization server **48**.

FIG. **3** depicts an exemplary implementation of a CSCD **34** of FIG. **2** in further detail. A CSCD **34** is typically a user terminal having a unique and tamper-proof DeviceID. CSCD **34** includes a network interface **60** for connecting to network **32**; an input/output interface **62** for connecting to a USB device **36**, a display device **64**, and/or one or more input devices **66** (such as, for example, a keyboard, keypad, mouse, trackpad, trackball, touch-sensitive device, or any similar devices); a controller **66** (such as, for example, a processor, microprocessor, central processing unit, or dedicated circuitry); and memory **68**. Memory **68** may include any type of volatile or non-volatile storage, such as, random access memory, read-only memory, flash memory, magnetic storage, optical storage, or any combination thereof. Memory **68** stores a virtual machine (VM) client **70**, which may be executed by controller **66**. Memory **68** also stores data used by VM client **70**. Memory **68** may also store other well-known elements, such as, for example, an operating system, system settings, and user data.

As shown in FIG. **3**, the memory **68** also comprises an endpoint session creation process **800** and a route list **1100**. Generally, as discussed further below in conjunction with FIG. **11**, the route list **1100** is a routing employed by the CSCD **34** to identify an appropriate virtualization server **48** for a given communication with a desired application server **42**. As discussed hereinafter, the route list **1100** is preferably generated or updated by the CSCD **34** each time the CSCD **34** accesses a new virtualization server **48**. In one exemplary embodiment, to ensure high availability, the route list **1100** contains pointers to a plurality of modules on a plurality of different virtualization platforms **500**. The exemplary route list **1100** is based on a hash tree format that indicates a distance to a given module **600**. As discussed further below in conjunction with FIGS. **8** through **10**, the route list **1100** is generated based on gossip data provided between the modules assessing the performance of other modules **600**. In addition, as discussed further below in conjunction with FIG. **8**, the route list **1100** can be regenerated from a bootstrap point.

Generally, as discussed further below in conjunction with FIG. **8**, the endpoint session creation process **800** evaluates the collected gossip data and selects an appropriate module **600** to serve as a virtualization server **48** for a given virtual session with a desired application server **42**.

FIG. **4** depicts an exemplary implementation of a virtualization server **48** of FIG. **2** in further detail. Virtualization server **48** includes a network interface **76** for connecting to network **32**, a controller **78** (such as, for example, a processor, microprocessor, central processing unit, or dedicated circuitry), and memory **80**. Memory **80** may include any type of volatile or non-volatile storage, such as, random access memory, read-only memory, flash memory, magnetic storage, optical storage, or any combination thereof. Memory **80** stores a secure browser program **82**, a VM dispatcher **84**, and a set of VM containers **86** (depicted as VM containers **86**(*a*)-**86**(*c*)). Each VM container **86** contains data for a virtual machine session with a CSCD **34** and may include an instance of browser **82**. Memory **80** also stores other well-known elements, such as, for example, an operating system, system settings, and user data. Dispatcher **84** includes several elements, including an interface **88**, a dispatch controller **90**, and a user database **92**.

In operation, a user wishing to process an online transaction, such as a commercial banking transaction, or otherwise engage in secured communication **50** with an application server **42** (such as a web banking server) uses a CSCD **34** to establish a secure VM session (using VM client **70**) on virtualization server **48**. The user is then able to run an instance of browser **82** on the virtualization server **48** (in a VM context) in order to access application server **42**. Because browser **82** is secure and run on a secure environment, the user may rest assured than there is no malware running within the VM session on the virtualization server **48**, thereby increasing the security of the communications **50**. Further security can be ensured once data has left the virtualization server **48** for the CSCD **34**, as will be described in further detail below.

In order to ensure that no malware is running within the VM client **70**, various methods may be used. In some embodiments, the user is provided with a copy of the VM client **70** software on a portable USB storage device **36**, which the user may then attach to his CSCD **34**. In one embodiment, the USB storage device **36** may be read-only, thereby preventing the VM client software from being modified by malware. The user is then able to securely run the VM client **70** directly from the USB storage device **36**. In other embodiments, the user downloads the VM client **70** across network **32**. Upon proper authentication, the user is able to obtain and install the VM client **70**. For example, the authentication can determine whether the user, typically identified by a userID, is authorized to access the application server **42** (such as, by determining if the user has an established account at the bank). The authentication server **44** can also communicates with the user using a strong authentication method to ensure that the user is not masquerading by altering his identity. See, for example, FIG. 4 of the '641 U.S. patent application, for an exemplary method for authenticating the user and providing the VM client **70**.

Once the user has successfully installed the VM client **70** on CSCD **34**, the user is able to use the VM client **70** to establish a VM session with virtualization server **48**, according to an appropriate login method. See, for example, FIG. 5 of the '641 U.S. patent application, for an exemplary method for establishing a VM session with virtualization server **48**.

Once the user has properly logged in to the application server **42** using the VM client **70**, the user is able to securely communicate with application server **42** via the virtualization server **48**. See, for example, FIG. 6 of the '641 U.S. patent application, for an exemplary method for secure communications between the CSCD **34** and the application server **42** via the virtualization server **48**.

In some embodiments, browser **82** renders all web pages provided by application server **42** and sends the fully rendered images back to the VM client **70** running on CSCD **34**. The fully rendered image may be a bitmap that represents what the web page is supposed to look like. The bitmap may be displayed to the user on screen **64** without further processing. This prevents any malware running on the CSCD **34** from modifying the web pages sent by the application server **42**, since it is difficult for malware to convincingly modify a rendered page image. It also helps secure the data transmitted within the web page against eavesdropping, because it is difficult for malware to interpret data contained within a rendered page image, while it is quite easy for a human user to do so.

After the user is done with an online banking session, or any other session with application server **42**, all data collected by the virtualization server **48** during the session can be destroyed. Therefore, no malware can be installed on the virtualization server **48** in normal operation and no user passwords are stored on virtualization server **48**. This disposable characteristic of the virtual environment ensures the security of the virtual environment, and reduces the risk of malicious intrusion into the communications between a user and the application server **42**. Thus, upon the user attempting to log back into the application server **42**, a new VM session is established having the original pre-configured settings stored in the user database **92**.

FIG. **5** is a schematic block diagram of an exemplary virtualization platform **500** incorporating features of the present invention. As shown in FIG. **5**, the exemplary virtualization platform **500** comprises a site controller **510**, a plurality of modules **600-1** through **600-4** (collectively, modules **600**) and a set of shared communication devices **530**. The plurality of modules **600** helps to ensure high availability. An exemplary module **600** is discussed further below in conjunction with FIG. **6**. Generally, each module **600** can serve as an instance of a virtualization server **48** of FIGS. **1** and **2**. The set of shared communication devices **530** comprise, for example, firewalls and a load balancer. The site controller **510** of a given virtualization platform **500** collects gossip data from other virtualization platforms **500** and controls communications with other virtualization platforms **500**. In addition, the site controller **510** routes sessions between modules **600** within the same virtualization platform **500**, implicitly via the gossip data. In addition, the virtualization platform **500** controls the modules **600** (such as powering down and configuration).

FIG. **6** is a schematic block diagram illustrating an exemplary module **600** of FIG. **5** in further detail. As shown in FIG. **6**, the exemplary module **600** comprises at least one front end machine **610** having a dispatcher front end **620**, an SSL gateway **630** and a virtual machine (VM) container **640**. In addition, the exemplary module **600** comprises at least one back end machine **650** having a dispatcher back end **660**, a user database **670** and a state database **680**. The front end machine **610** preferably has a physical separation from the back end machine **650**.

Generally, the exemplary SSL gateway **630** transforms SSL communications to Remote Desktop Connection/Virtual Network Computing (RDP/VNC) communications. The dispatcher front end **620** operates in a similar manner to the VM dispatcher **84** of FIG. **4**. The virtual machine (VM) containers **640** operate in a similar manner to the VM containers **86** of FIG. **4**. The dispatcher back end machine **660** performs the gossip collection from other modules. The user database **670** stores user session data and the state database **680** stores configuration data and the collected gossip data.

FIG. **7** illustrates the selection of a particular module **600** by a CSCD **34** using a route list **1100**, in accordance with an aspect of the present invention. As shown in FIG. **7**, the route list **1100** contains pointers **730-1** through **730-4** to various modules among two virtualization platforms **500-1**, **500-2**. In one embodiment, once the CSCD **34** selects a module **600** from the route list **1100**, the CSCD **34** can communicate directly with the selected module **600**, for example, using an RDP protocol over SSL. As shown in FIG. **7**, and discussed further below in conjunction with FIG. **8**, the route list **1100** includes a pointer **730-4** to one or more bootstrap points **710** that are dedicated devices, generally providing a high availability, that provide a starting point for the creation of the route list **1100**.

For a more detailed discussion of suitable techniques for the selection of a module **600**, see, for example, G. DeCandia et al., "Dynamo: Amazon's Highly Available Key-Value Store," SOSP 2007 (Oct. 14, 2007), incorporated by reference herein.

FIG. **8** is a flow chart describing an exemplary implementation of an endpoint session creation process **800**. Generally, as indicated above, the endpoint session creation process **800** evaluates the collected gossip data and selects an appropriate module **600** to serve as a virtualization server **48** for a given virtual session with a desired application server **42**.

As shown in FIG. **8**, the endpoint session creation process **800** initially performs a test during step **810** to determine if a route list **1100** exists. If it is determined during step **810** that a route list **1100** does not exist, then program control proceeds to step **820**, where a call is made to a bootstrap server **710**. An initial route list **1100** is obtained from the bootstrap server **710** during step **830** (or the location of one module **600** to start the process) and program control proceeds to step **840**.

If, however, it is determined during step **810** that a route list **1100** exists, then the endpoint session creation process **800** scans the list **1100** during step **840**. The device parameters (e.g., a performance score) from the list **1100** are assessed during step **850**. For example, the location of each module **600** in the list **1100**, relative to the CSCD **34** can be assessed. The endpoint session creation process **800** attempts to connect to the "best match" from the list **1100** during step **860**.

A test is performed during step **870** to determine if the connection was successful. If it is determined during step **870** that the connection was not successful, then a further test is performed during step **875** to determine if a maximum number of tries have been attempted. If it is determined during step **875** that a maximum number of tries have not been attempted, then the list **1100** is reassessed during step **880** and program control returns to step **860** and continues with another connection attempt. For example, if a module **600** in one geographic area failed, then a module **600** in another geographic area can be attempted on the re-try. If, however, it is determined during step **875** that a maximum number of tries have been attempted, then the bootstrap server **710** is contacted again during step **885** for another starting point.

If, however, it is determined during step **870** that the connection was successful, then the session is started during step **890**. For example, an authentication process can be implemented during step **890**. A new list is sent to the CSCD **34** during step **895** for the next session. In this manner, the endpoint session creation process **800** selects an appropriate module **600** for each session.

FIG. **9** illustrates the communication of gossip data among modules **600**. In particular, FIG. **9** illustrates exemplary peer-to-peer communications **910** from a first module **600-1** within a given virtualization platform **500-1** to one or more additional modules **600-2**, **600-3**, **600-4**. For example, the communication **910** can notify the additional modules **600-2**, **600-3**, **600-4** that the first module **600-1** is "almost full" or nearing full capacity. One or more of the modules **600-1**, **600-2**, **600-3**, **600-4** can also relay one or more messages **920** to one or more additional modules **930** in other virtualization platforms **500**, such as platform **500-2**. For a more detailed discussion of an exemplary fault tolerance approach for the collection of gossip data, see, for example, L. Lamport et al., "The Byzantine Generals Problem," ACM Trans. On Programming Languages and Systems, Vol. 4, No. 3, 382-401 (July 1982), incorporated by reference herein.

FIG. **10** is a flow chart describing an exemplary process **1000** that may be performed by a module **600** to process the gossip that is collected. As shown in FIG. **10**, a given module **600** may generate a list during step **1010** of the servers known by the module **600**. Thereafter, during step **1020**, those other modules **600** that are known to be unavailable are deleted from the list. For example, a module **600** may be unavailable if it failed a ping, sent a "module full" message, or sent a "going down" message and no "module reinstatement" message was received.

The remaining servers on the list are ranked during step **1030**. For example, the ranking can be based on a response time from other modules **600**, a proportional distance from the current module **600**, and whether the current module **600** has recently connected to another module **600**. During step **1040**, the top N modules **600** are selected for consideration. The top N modules **600** can be a number of "local" modules, as well as a number of geographically distributed modules **600**. For example, modules **600** can have a state of just started; almost full; going down or not available (provided, e.g., by other modules **600** pinging the module).

FIG. **11** is a sample table from an exemplary route list **1100** incorporating features of the present invention. As shown in FIG. **11**, the exemplary route list **1100** comprises a plurality of records **1110-1** through **1110-3**, each associated with a different module **600**. For each module **600**, identified by a server URL in field **1120**, the route list **1100** provides a geographic descriptor in field **1130** identifying where the module **600** is located, and a performance hashcode in field **1140**. The exemplary server URL identifies a domain associated with the module **600**, and the particular machine of the domain. The exemplary performance hashcode is a coded ranking based, for example, on a site rank, a history of all modules, as well as a number of available machines and a minimum response time. The various components of the exemplary performance hashcode can optionally be weighted. In one exemplary implementation, the exemplary performance hashcode comprises a distance metric, a number of available machines, a number of node failures and a mean time between failures. The exemplary route list **1100** employs a hashcode format that is based on Merkel Trees. For a more detailed discussion of Merkel Trees, see, for example, http://en.wikipedia.org/wiki/Hash_tree, incorporated by reference herein. Among other benefits, a Merkel Tree format allows the hashcode to indicate a ranking for each virtualization platform **500** and module **600**, as well as the speed and uptime in a tree model.

The disclosed virtualization platforms **500** permit users to work from a secure virtual environment, taking the form of a disposable browser environment, without direct interaction between malware and the remote application server, such as an online banking site.

As mentioned previously herein, the above-described embodiments of the invention are presented by way of illustrative example only. Numerous variations and other alternative embodiments may be used.

For example, it should be understood, that while the application server **42** and the authorization server **44** are typically under the control of an application service provider, such as a bank, the virtualization server **48** and client install server **46** may be under the control of a separate virtualization service provider. Thus, one virtualization provider may contract with multiple banks and other entities to provide virtualization services. Therefore, there may be one virtualization server **48** to service a multitude of different application servers **42**, each application server **42** potentially representing a different bank or other secure entity. The application service providers are not limited to banks, but may include, for example, online gaming sites or any other sites requiring a high degree of security. In some cases, several banks will contract with a single entity to provide a single authorization server **44** for a plurality of banks.

It should be understood that the risk-based authentication performed by the authentication server **44**, in some embodiments, is capable of utilizing RSA® Adaptive Authentication which is offered by EMC Corporation of Hopkinton, Mass. Certain aspects of RSA® Adaptive Authentication relate to risk-based authentication (RBA) and fraud detection which involve measuring over one hundred risk indicators to identify high-risk and suspicious activities. Certain aspects of RSA® Adaptive Authentication are powered by risk-based authentication technology that conducts a risk assessment of all users behind the scenes. A unique risk score is assigned to each activity, and users are only challenged when an activity is identified as high-risk and/or an organizational policy is violated. This transparent authentication enables organizations to increase security without compromising user convenience. Certain aspects of Adaptive Authentication monitor and authenticate activities based on risk, profiles, and policies by correlating: unique browser identification profiles, matching banking behavioral patterning profiles and inputs from our fraud intelligence teams that locate compromised IP addresses and accounts.

It should be understood that browser **82** may refer to a web browser or to any other type of program used to render and display markup files in a form suitable for viewing by humans. Numerous other known password protection techniques can be used in conjunction with the present invention. Additional details regarding certain conventional cryptographic techniques referred to herein may be found in, e.g., A. J. Menezes et al., Handbook of Applied Cryptography, CRC Press, 1997, which is incorporated by reference herein.

The term "authentication information" as used herein is intended to include passwords, passcodes, answers to life questions, or other authentication credentials, or values derived from such authentication credentials, or more generally any other information that a user may be required to submit in order to obtain access to an access-controlled application. Although the illustrative embodiments will be described below in the context of passwords, it is to be appreciated that the invention is more broadly applicable to any other type of authentication information.

It should be understood that although various embodiments have been described as being methods, software embodying these methods is also included. Thus, one embodiment includes a tangible computer-readable medium (such as, for example, a hard disk, a floppy disk, an optical disk, computer memory, flash memory, etc.) programmed with instructions, which, when performed by a computer or a set of computers, cause one or more of the methods described in various embodiments to be performed. Another embodiment includes a computer which is programmed to perform one or more of the methods described in various embodiments.

Furthermore, it should be understood that all embodiments which have been described may be combined in all possible combinations with each other, except to the extent that such combinations have been explicitly excluded.

It should again be emphasized that the particular security techniques described above are provided by way of illustration, and should not be construed as limiting the present invention to any specific embodiment or group of embodiments. For example, the particular configuration of system elements shown in FIGS. **1** through **7**, and their interactions as shown in FIGS. **8** through **10**, may be varied in other embodiments. Moreover, the various simplifying assumptions made above in the course of describing the illustrative embodiments should also be viewed as exemplary rather than as requirements or limitations of the invention. Numerous alternative embodiments within the scope of the appended claims will be readily apparent to those skilled in the art.

What is claimed is:

1. A method, performed in a client-side computing device, for performing secured communications during a virtual session with an application server across a network, the method comprising:

selecting a remote module, from multiple remote modules, to serve as a virtualization server for the virtual session on the client-side computing device based on performance factors associated with each of the multiple remote modules, wherein said performance factors are (i) related to an availability status of each of the multiple remote modules, and (ii) communicated among the multiple remote modules via peer-to-peer communication, and wherein said selecting comprises:

ranking the multiple remote modules based on at least a weighted portion of said performance factors, said portion comprising (a) a response time of each of the multiple remote modules, and (b) a proportional distance of each of the multiple remote modules from the client-side computing device; and

selecting the highest ranked remote module subsequent to said ranking the multiple remote modules;

establishing the virtual session with the selected module, the selected module being distinct from the application server; and

performing secured communications between the client-side computing device and the application server via the virtual session of the selected module.

2. The method of claim **1**, wherein the virtual session is initialized to a pre-configured state upon establishment.

3. The method of claim **1**, wherein the performance factors are collected from a plurality of modules using a gossip-based state notification process.

4. The method of claim **1**, wherein the client-side computing device stores the performance factors for a plurality of modules.

5. The method of claim **1**, wherein the step of selecting a remote module to serve as a virtualization server evaluates a route list that stores the performance factors for a plurality of modules.

6. The method of claim **5**, wherein the route list contains pointers to a plurality of remote modules in a plurality of virtualization platforms.

7. The method of claim **5**, wherein the route list is based on a hash tree format that indicates a distance to a given module.

8. The method of claim **5**, wherein the route list is generated based on gossip data provided among a plurality of modules to assess the performance of each module.

9. The method of claim **5**, wherein the route list can be generated from a bootstrap point.

10. The method of claim **5**, wherein the route list comprises a hashcode for each module, wherein said hashcode comprises one or more of a distance metric and a performance metric.

11. The method of claim **1**, wherein the remote module can be replaced in the event of a failure.

12. The method of claim **1**, wherein the step of perfo ming secured communications between the client-side computing device and the application server further comprises the steps of:

running a secure browser within the virtual session of the virtualization server; and

communicating between the client-side computing device and the application server through the secure browser.

13. A tangible machine-readable storage device for storing one or more software programs for use in a client-side computing device to perform secured communications during a virtual session with an application server across a network, controlling user access to an access-controlled resource, wherein the one or more software programs when executed by one or more processing devices implement the steps of the method of claim **1**.

14. A client-side computing device, for performing secured communications during a virtual session with an application server across a network, the client-side computing device comprising:

a memory; and

at least one processor, coupled to the memory, operative to implement the following steps:

selecting a remote module, from multiple remote modules, to serve as a virtualization server for the virtual session on the client-side computing device based on performance factors associated with each of the multiple remote modules, wherein said performance factors are (i) related to an availability status of each of the multiple remote modules, and (ii) communicated among the multiple remote modules via peer-to-peer communication, and wherein said selecting comprises:

ranking the multiple remote modules based on at least a weighted portion of said performance factors, said portion comprising (a) a response time of each of the multiple remote modules, and (b) a proportional distance of each of the multiple remote modules from the client-side computing device; and

selecting the highest ranked remote module subsequent to said ranking the multiple remote modules;

establishing the virtual session with the selected module, the selected module being distinct from the application server; and

performing secured communications between the client-side computing device and the application server via the virtual session of the selected module.

15. The client-side computing device of claim **14**, wherein the virtual session is initialized to a pre-configured state upon establishment.

16. The client-side computing device of claim **14**, wherein the performance factors are collected from a plurality of modules using a gossip-based state notification process.

17. The client-side computing device of claim **14**, further comprising a route list in the memory for storing the performance factors for a plurality of modules.

18. The client-side computing device of claim **17**, wherein the route list contains pointers to a plurality of remote modules in a plurality of virtualization platforms.

19. The client-side computing device of claim **17**, wherein the route list is based on a hash tree format that indicates a distance to a given module.

20. The client-side computing device of claim **17**, wherein the route list is generated based on gossip data provided among a plurality of modules to assess the performance of each module.

21. The client-side computing device of claim **17**, wherein the route list can be generated from a bootstrap point.

22. The client-side computing device of claim **17**, wherein the route list comprises a hashcode for each module, wherein said hashcode comprises one or more of a distance metric and a performance metric.

23. The client-side computing device of claim **14**, wherein the remote module can be replaced in the event of a failure.

24. The client-side computing device of claim **14**, wherein said processor is further configured to perform secured communications between the client-side computing device and the application server by executing a secure browser within the virtual session of the virtualization server; and communicating between the client-side computing device and the application server through the secure browser.

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